

Regional pulmonary blood flow after mitral valve surgery

Bohuslav Král, Iva Křivková, Jiří Endrys, Jaroslav Procházka, Jiří Kubiček, Ivan Jurin, Zdeněk Bělobrádek, Ivan Kosmák, and Jiří Kvasnička

From the 2nd Department of Medicine, the Department of Surgery, the Department of Radiology, and the 1st Department of Medicine of the Faculty of Medicine, Charles University, Hradec Králové, Czechoslovakia

The authors investigated the index of pulmonary blood flow distribution between the upper and lower parts of the lungs in three groups of patients with acquired valvular heart disease before, and 3 and 12 months after surgical correction for mitral and aortic valve disease.

Three and 12 months after mitral valvotomy, there was a statistically significant decrease in the perfusion of the upper parts of the lungs. Three months after prosthetic mitral valve replacement, these changes were even more prominent. Three months after prosthetic aortic valve replacement, there were no changes in the index of distribution of pulmonary blood flow.

This method of measurement of the distribution of pulmonary blood flow is of value in the assessment of the results of mitral valve surgery.

Surgical correction of acquired mitral valve disease has been practised for more than 20 years. The assessment of the results of surgical treatment is based mainly on evaluation of symptoms and clinical, radiological, and electrocardiographic data (Ellis *et al.*, 1965; Keith and Fowler, 1972; Rees, Holswade, and Lillehei, 1972; Salzmann *et al.*, 1972; Selzer and Cohn, 1972). Haemodynamic investigation cannot be undertaken in every patient after operation, for various reasons, e.g. patient's refusal, risks of the procedure, etc.

A good correlation between mean left atrial, and pulmonary arterial pressure, and the degree of redistribution of pulmonary blood flow to the upper parts of the lungs in patients with postcapillary pulmonary hypertension has often been found (Bell *et al.*, 1971; Dawson, Kaneko, and McGregor, 1965; Dollery and West, 1960; Friedman and Braunwald, 1966; Hughes *et al.*, 1969; Jebavý *et al.*, 1970; Sester, 1971; Steiner and Quinn, 1968). We have confirmed that the radioisotope technique for the measurement of the distribution of pulmonary blood flow is useful as an indirect assessment of the mean left atrial pressure in patients with mitral valve disease (Endrys, Král, and Dvořák, 1968).

Patients and methods

We investigated 21 patients with predominant mitral

stenosis, in whom mitral valvotomy was performed; 10 patients had mitral stenosis and regurgitation, and a prosthetic mitral valve replacement was done. For comparison, we studied 6 patients with aortic valve disease, in whom the aortic valve was replaced by a prosthesis. In all but 4 patients, the left atrial mean pressure and other haemodynamic parameters were measured before operation.

The index of pulmonary blood flow distribution between the upper and lower parts of the lungs was measured by ^{133}Xe method of Oppelt *et al.* (1966). Two scintillation counters were positioned behind the chest of the seated subject. The apical counter was placed at the level of the clavicle on the left side, and the basal counter at the level of the fifth anterior intercostal space in the midscapular line on the right side. Distribution of perfusion was studied by injecting 0.5-1.0 mCi ^{133}Xe in saline intravenously while the patient held his breath in full inspiration (\dot{Q}). After equilibration of xenon in the lung spirometer system by rebreathing, the breath-holding manoeuvre was repeated to determine the regional lung volume (V). The levels of activity recorded during each breath-holding period were measured in counts per minute. The index of pulmonary blood flow distribution (IDPBF) was then calculated according to the formula: $\text{IDPBF} = \frac{\dot{Q}/V_{\text{apical}}}{\dot{Q}/V_{\text{basal}}}$. In our control sub-

jects the value of this index was 0.25-0.60.

Measurements of the distribution index were made before operation, and again at 3 months and 12 months, and in 5 patients 4 to 5 years, after operation.

The characteristics of patients investigated in this

TABLE 1 *Group 1, mitral valvotomy*

Case No.	Sex	Age	Diagnosis	Functional class	Left atrial mean pressure (mmHg)	I ₁	I ₂	I ₃	I ₄	ΔI_1-I_2	ΔI_1-I_3	ΔI_1-I_4
1	F	35	Mitral stenosis	3	22.0	2.68	1.41	1.25	0.86	+1.27	+1.43	+1.82
2	F	40	" "	3	33.0	1.62	—	0.83	—	—	+0.79	—
3	F	45	Mitral stenosis and regurgitation	4	24.0	1.32	1.42	1.12	0.85	-0.10	+0.20	+0.47
4	F	35	Mitral stenosis	3	—	1.41	1.02	0.79	—	+0.39	+0.62	—
5	F	45	Mitral stenosis and regurgitation, tricuspid stenosis	4	14.0	1.04	—	1.22	—	—	-0.18	—
6	M	30	Mitral stenosis	3	21.0	1.14	0.88	0.68	—	+0.26	+0.46	—
7	M	40	" "	3	19.0	1.12	0.87	0.75	—	+0.25	+0.37	—
8	F	35	" "	3	24.0	0.92	0.90	—	—	+0.02	—	—
9	F	30	" "	3	19.0	2.02	1.20	1.20	—	+0.82	+0.82	—
10	F	32	" "	2	8.5	0.69	0.79	0.73	0.91	-0.10	-0.04	-0.22
11	F	39	" "	3	26.0	1.94	—	1.22	—	—	+0.72	—
12	F	38	" "	3	19.0	1.01	—	1.13	—	—	-0.12	—
13	M	36	" "	3	20.0	1.68	1.15	0.86	0.61	+0.53	+0.82	+1.07
14	F	34	" "	3	34.0	1.86	0.82	—	0.49	+1.04	—	+1.37
15	F	28	" "	3	17.0	0.98	0.67	—	—	+0.31	—	—
16	F	36	" "	3	—	1.86	—	1.00	—	—	+0.86	—
17	F	38	" "	4	23.0	2.32	—	0.94	—	—	+1.38	—
18	M	40	" "	3	25.0	1.00	0.73	—	—	+0.27	—	—
19	F	39	Mitral stenosis, tricuspid stenosis and regurgitation	4	38.0	1.53	1.30	—	—	+0.23	—	—
20	M	38	Mitral stenosis	3	20.0	0.86	0.63	—	—	+0.23	—	—
21	F	21	Mitral stenosis, mitral regurgitation	3	—	1.25	0.80	—	—	+0.45	—	—

Footnotes: I = index of distribution of pulmonary blood flow between upper and lower lung field.

I₁ = before operation.

I₂ = 3 months after operation.

I₃ = 1 year after operation.

I₄ = 4 to 5 years after operation.

study and the results are presented in Tables 1, 2, and 3. The statistical evaluation of the data was made with the aid of the t-test and correlation coefficients.

Results

Fig. 1 shows a correlation between the mean left atrial pressure and the index of distribution of pulmonary blood flow in patients of all 3 groups investigated. In another group of patients with mitral valve disease, investigated previously, we found a better correlation between these two parameters ($r=0.784$) (Endrys *et al.*, 1968). There is progressively less diversion of pulmonary blood flow to the upper part of the lung 3 and 12 months after operation, the difference being more pronounced in patients after mitral valve replacement (Fig. 2 and 3, Tables 4 and 5). The distribution of pulmonary blood flow in patients with aortic heart valve disease

was only slightly abnormal before operation and did not change significantly after operation (Fig. 3). The decrease in the index of distribution of pulmonary blood flow after mitral valve surgery was greater, the more abnormal the index before operation (Fig. 4).

Discussion

Many reports have shown the tendency of pulmonary artery and left atrial pressure and of pulmonary vascular resistance to return to normal values after mitral valve operations (Braunwald *et al.*, 1965; Carey and Plested, 1972; Dalen *et al.*, 1967; Donald *et al.*, 1957; Graham *et al.*, 1971; Heinz *et al.*, 1972; Hoffmeister *et al.*, 1972; Lee *et al.*, 1971; Moccetti *et al.*, 1970, 1972; Morrow *et al.*, 1967; Mullin *et al.*, 1972; Reeve *et al.*, 1966; Semler, Shepherd, and Wood, 1959). These

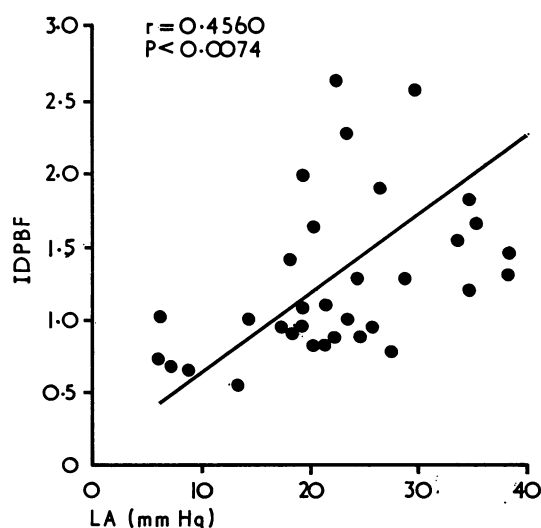


FIG. 1 Mean left atrial pressure (LA) in relation to the index of distribution of pulmonary blood flow (IDPBF) in patients with acquired valvular heart disease. The correlation coefficient ($r = 0.456$) is statistically significant ($P < 0.01$).

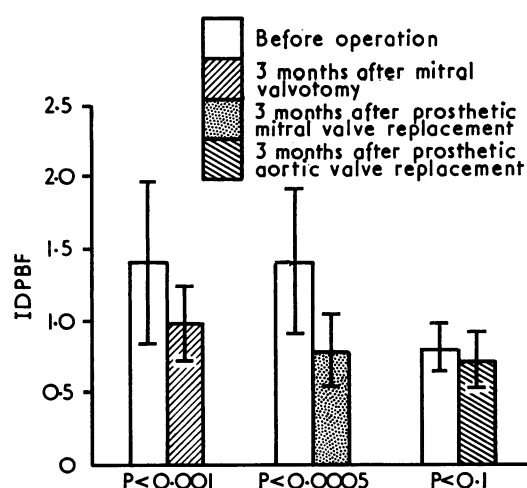


FIG. 3 The index of distribution of pulmonary blood flow (IDPBF) before and 3 months after mitral valvotomy, prosthetic mitral valve replacement, and prosthetic aortic valve replacement. The most striking decrease in the index is seen after mitral valve replacement; this was less in mitral valvotomy patients; there was no difference after aortic valve replacement.

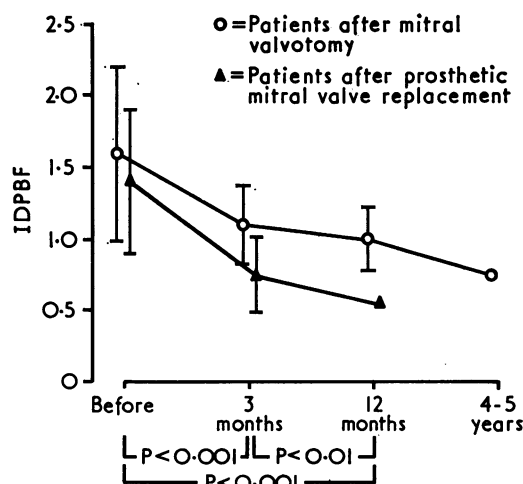


FIG. 2 The index of distribution of pulmonary blood flow (IDPBF) before, 3, and 12 months, and 4 to 5 years after mitral valvotomy (open circles) and after prosthetic mitral valve replacement (squares). The differences found 3 and 12 months after mitral valvotomy and after mitral valve replacement are statistically highly significant.

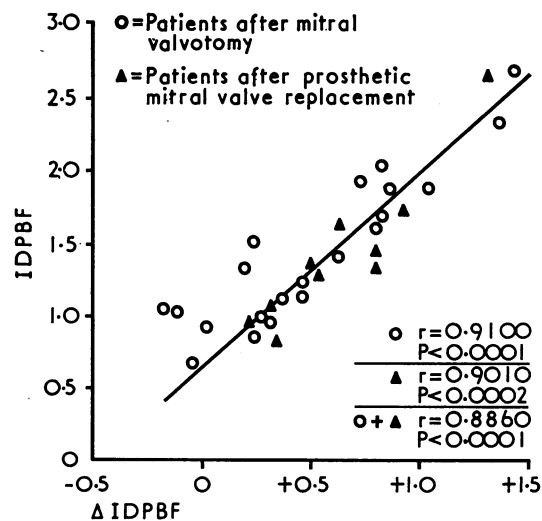


FIG. 4 The preoperative value of the index of distribution of pulmonary blood flow (IDPBF) is related to the difference between preoperative and postoperative values (Δ IDPBF). A highly significant correlation index ($r = 0.886$) can be seen in both groups of patients investigated in this study.

TABLE 2 *Group 2, prosthetic mitral valve replacement*

Case No.	Sex	Age	Diagnosis	Functional class	Left atrial mean pressure	I_1	I_2	I_3	I_4	ΔI_1-I_2	ΔI_1-I_3	ΔI_1-I_4
22	F	26	Mitral stenosis	3	29.0	2.62	1.31	—	—	+1.31	—	—
23	F	36	Mitral stenosis, tricuspid stenosis, tricuspid regurgitation, aortic stenosis	4	23.0	1.08	0.77	0.71	—	+0.31	+0.37	—
24	M	34	Mitral stenosis, mitral regurgitation	4	38.0	1.36	0.87	0.73	—	+0.49	+0.63	—
25	M	37	Mitral stenosis, mitral regurgitation	3	28.0	1.29	0.49	0.23	—	+0.80	+1.06	—
26	F	41	Mitral stenosis, mitral regurgitation	3	27.0	0.82	0.49	0.60	—	+0.33	+0.22	—
27	M	38	Mitral stenosis, mitral regurgitation	3	18.0	1.43	0.52	—	—	+0.91	—	—
28	M	36	Mitral stenosis, mitral regurgitation	4	35.0	1.72	0.80	—	—	+0.92	—	—
29	M	37	Mitral stenosis, mitral regurgitation	3	34.0	1.26	0.72	—	—	+0.54	—	—
30	F	33	Mitral stenosis, tricuspid stenosis, aortic stenosis	4	18.0	0.95	0.72	—	—	+0.23	—	—
31	F	39	Mitral stenosis, mitral regurgitation	3	—	1.62	0.99	—	—	+0.63	—	—

Note: See footnote to Table 1 for explanation of column headings.

TABLE 3 *Group 3, prosthetic aortic valve replacement*

Case No.	Sex	Age	Diagnosis	Functional class	Left atrial mean pressure	I_1	I_2	I_3	I_4	ΔI_1-I_2	ΔI_1-I_3	ΔI_1-I_4
32	M	38	Aortic stenosis, aortic regurgitation	2	6.0	0.76	0.42	0.56	—	+0.34	+0.20	—
33	M	36	Aortic stenosis, aortic regurgitation	4	22.0	0.89	0.92	0.64	—	-0.03	+0.25	—
34	F	33	Mitral stenosis, aortic stenosis, aortic regurgitation	3	7.0	0.71	0.55	—	—	+0.16	—	—
35	M	41	Aortic regurgitation	3	6.0	1.07	0.87	—	—	+0.20	—	—
36	M	33	Aortic stenosis, aortic regurgitation	3	21.0	0.87	0.89	—	—	-0.02	—	—
37	F	28	Aortic stenosis, aortic regurgitation	2	13.0	0.57	0.63	—	—	-0.06	—	—

Note: See footnote to Table 1 for explanation of column headings.

TABLE 4 Statistical evaluation of changes in distribution of pulmonary blood flow 3 months, 12 months, and 4 to 5 years after mitral valvotomy

Index (IDPBF)			Index (IDPBF)			Index (IDPBF)		
No.	Before	3 months after operation	No.	Before	12 months after operation	No.	Before	4 to 5 years after operation
16	1.423 ± 0.56	0.970 ± 0.25	13	1.511 ± 0.48	0.980 ± 0.22	5	1.621 ± 0.68	0.745 ± 0.21
P < 0.001			P < 0.001			—		

TABLE 5 Statistical evaluation of changes in distribution of pulmonary blood flow 3 and 12 months after prosthetic mitral valve replacement

Index (IDPBF)			Index (IDPBF)		
No.	Before	3 months after operation	No.	Before	12 months after operation
10	1.415 ± 0.50	0.768 ± 0.25	4	1.140	0.528
P < 0.0005			—		

changes were greater and occurred earlier after mitral valve replacement than after mitral valvotomy. Our results are in good agreement with these haemodynamic observations.

The greatest decrease in the index of distribution of pulmonary blood flow after operation was observed in patients with the greatest abnormality of distribution of pulmonary blood flow before operation, caused perhaps by severe vasoconstriction in the lower parts of the lungs, and its immediate release after successful surgery. In 4 patients examined 4 to 5 years after mitral valvotomy there was a further decrease in the index, indicating further return towards normal pulmonary blood flow distribution. This could be a functional reflection of the continuing regression of anatomical changes in the pulmonary vasculature after successful relief of mitral valve obstruction (Nicks and McGovern, 1968). This observation is consistent with the results of Ferguson and Varco (1955), who found experimentally that the regression of pathological pulmonary vascular changes was a slow process.

We have found good agreement between the changes in distribution of pulmonary blood flow and the clinical symptoms and signs in these patients. Cases 5 and 12 had mitral regurgitation after operation, and the diversion of pulmonary blood flow to the parts of the upper lungs remained unchanged. Case 10 had systemic emboli before operation, but haemodynamically insignificant mitral stenosis. Four years after operation, there were signs of restenosis and the patient became breath-

less. In this patient, the index of pulmonary blood flow distribution was only slightly raised before operation, and increased at 4 to 5 years. Cases 13 and 14 had almost normal distribution of pulmonary blood flow 5 years after mitral valvotomy, when they had no residual disability.

Despite the indirect character of this method in evaluating pulmonary haemodynamics, we have found the measurement of the index of pulmonary blood flow distribution to be useful in the evaluation of the results of mitral valve surgery (Endrys et al., 1972). This is in agreement with other authors (Cellerino, Andreone, and Gaetini, 1971; Krishnamurthy, Srinivasan, and Blahd, 1971, 1972).

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Requests for reprints to Dr. Bohuslav Král, 2nd Department of Medicine, Faculty of Medicine, Hradec Králové Czechoslovakia.